REMOTELY SENSED CROP TEMPERATURE FOR WATER RESOURCES MANAGEMENT

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ABSTRACT

The overall goal of our research was to evaluate the use of crop temperature data as a tool in the management of water resources. The specific objectives of our studies were (1) to determine the crop temperature response of some major agronomic crops to various levels of water stress; (2) to test methods based on crop temperature or other remotely sensed data to estimate crop water stress conditions and to evaluate the utility of these methods for their ability to estimate crop yields, severity of water stress and crop phenological development, and (3) to determine the feasibility of using crop temperature as a guide for irrigation scheduling.

Crop temperatures were measured with an infrared thermometer, with attached leaf thermocouples and with airborne multispectral scanners. Corn and sorghum were the principal crops studied. Some data were also obtained for soybeans and alfalfa. Studies were conducted at the University of Nebraska Sandhills Agricultural Laboratory and at the University of Nebraska Mead Field Laboratory.

The primary findings of our research are summarized as follows:

1. After about 75% plant cover was achieved, the temperature of well-watered crops measured with an infrared thermometer (T_{ir}) agreed to within about 1 C of the temperature measured with attached leaf thermocouples (T_{TC}). For crops under water stress the agreement was found to be within about 2.5 C.

2. Different species of crops growing under similar climatic conditions and water regimes may have different canopy temperatures. This difference in canopy temperature relates to the crop water use for, in general, the cooler the crop the greater the transpiration and, hence, the water use rate.

3. Under fully irrigated conditions T_{ir} values were not affected by plant population but under water stress conditions T_{ir} was consistently 1-2 C warmer in plots with high plant populations than in plots with low plant populations.

4. Crop temperatures obtained at midday with an IR thermometer when the observed faced north and viewed leaves on the south sides of plants were similar to those obtained when the observed faced south under well-watered conditions. Under water stress conditions crop temperatures obtained when facing north were about 1-2 C warmer than those obtained when facing south.

5. Crop temperature at midday was found to be a function of the level of water stress. Water stressed plants were often 5 to 7 C warmer than nonstressed plants and differences as great as 12.8 C were observed. At night differences in crop temperature of stressed and non-stressed vegetation were negligible.

6. The optimum time to measure the maximum temperature difference between stressed and nonstressed crops was found, generally, between 1300 and 1500 hrs solar time. A good time to make crop temperature readings for water stress evaluation is about 1400 hrs.

7. Summation of the midday crop temperature differences (TSD) between water stressed and nonstressed corn during the pollination and grain filling periods was directly related to

decreases in final grain yield. In sorghum the grain yield reductions were directly related to TSD values accumulated over the entire growing season.

8. Similar percentage reduction in grain yields as a function of accumulated TSD values were observed for 9 hybrids of corn and 2 hybrids of sorghum.

9. With light to moderate water stress the canopy temperature of corn was often below air temperature at mid-day. Severely stressed plants, however, were several degrees warmer than air.

10. The time of day at which temperature difference between well-watered and stressed vegetation develops indicated the severity of stress. If the temperature difference appears by mid-morning the level of water stress was moderate to severe. If the difference did not become evident until mid-afternoon the stress was mild to moderate. A procedure for calculating a stress severity index based upon crop temperature measurements during the morning and afternoon was developed and evaluated.

11. The standard deviation of mid-day canopy temperature in plots of well watered corn and sorghum was about 0.3 C. Values exceeding 0.3 C indicate that some plants in a plot are experiencing water stress and the need for irrigation is indicated. Standard deviations of crop temperature under water stress conditions was found to be as great as 4.2 C.

12. Irrigations were scheduled in corn using crop temperature data. Grain yields from a plot in which irrigations were initiated when the range in crop temperatures across a plot reached 0.8 C (0.8 CTV) were not significantly different from the yields of a fully-irrigated plot. Only 120 mm of water was

applied to the 0.8 CTV plot as compared to 260 mm of water on the fully irrigated plot. Other irrigations were initiated when average plot temperatures became 1.0 or 3.0 C warmer than the well-watered plot. Yield was reduced most in the 3.0 C plot but even in the 1.0 C plot yield was reduced significantly.

13. Data from an airborne multispectral scanner showed slight, but detectable, increases in reflected visible and near infrared radiation with an increase in water stress of corn. These increases were small and would probably be less useful than observations in the thermal infrared portion of the spectrum for evaluating crop water status. Hail damage in corn, however, was readily detectable with the multispectral data.

14. Three of five crop temperature indices tested were highly correlated with the phenological growth stage of corn. These three indices could be used to monitor phenological development in corn and sorghum. Except under very severe conditions the water stress did not affect phenological development until near crop maturity.

Results of the studies summarized above suggest that crop temperature data can be used to assess crop water status. As such, crop temperature data can be used for scheduling irrigation; for detecting and monitoring effects of limited availability of water to crops, conditions which occur during drought and in semi-arid and arid regions; for evaluating the effectiveness of various irrigation scheduling techniques; for examining the uniformity of water application by various irrigation systems; for detecting soil areas with low water holding capacities; and as a means to select plant types which are most effective in tolerating or

avoiding shortages of water. Additional research is needed to further evaluate and quantify relationships between crop temperature and crop water status and to answer some of the questions raised in the conduct of our studies thus far.

Key words: Water stress, irrigation scheduling, crop temperature, infrared thermometry, plant temperature, canopy temperature, remote sensing, corn, sorghum, soybeans, irrigation, crop phenology, evapotranspiration, drought surveillance.